Future Space Concepts

Dr. David Whelan

Director

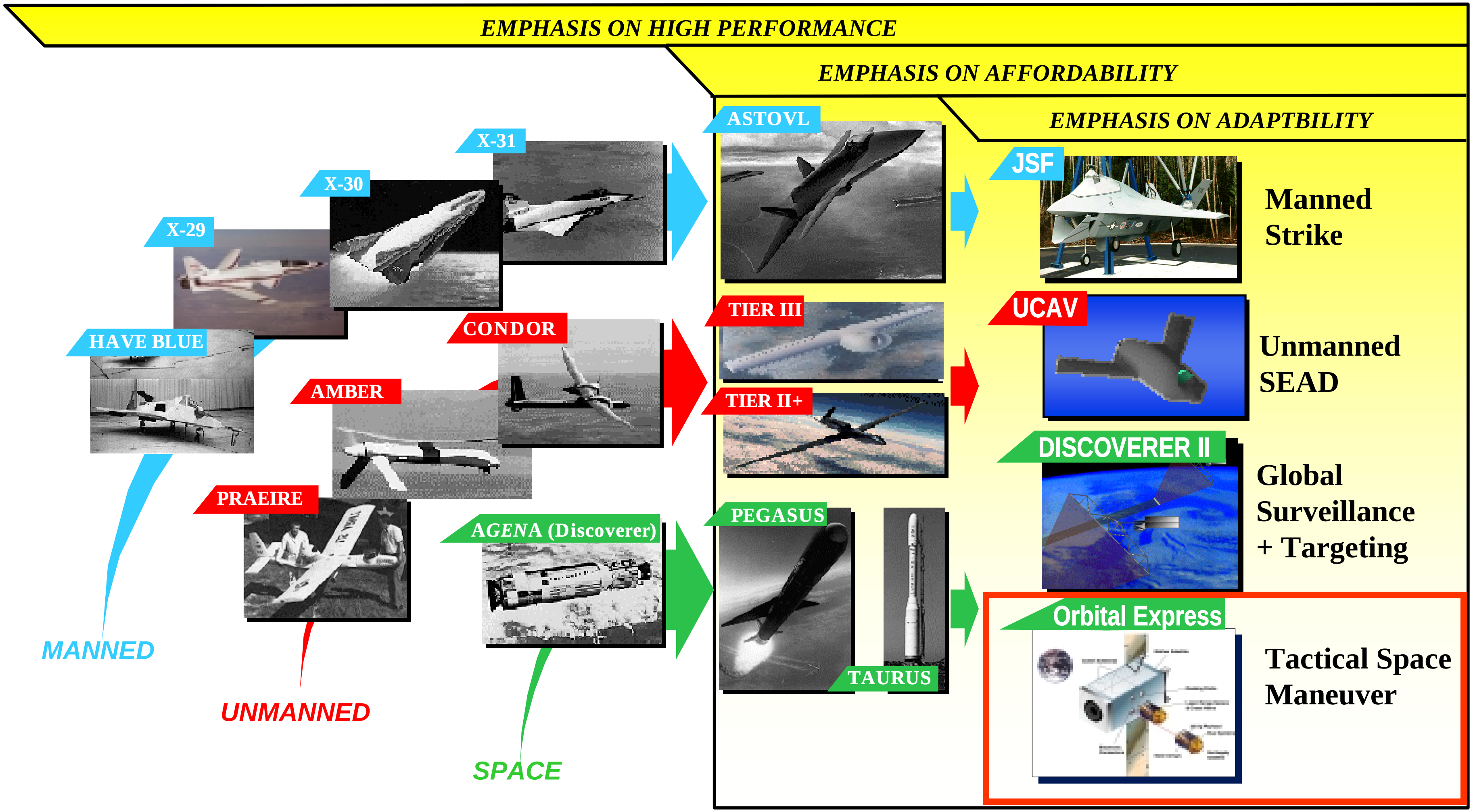
Tactical Technology Office

Defense Advanced Research Projects Agency

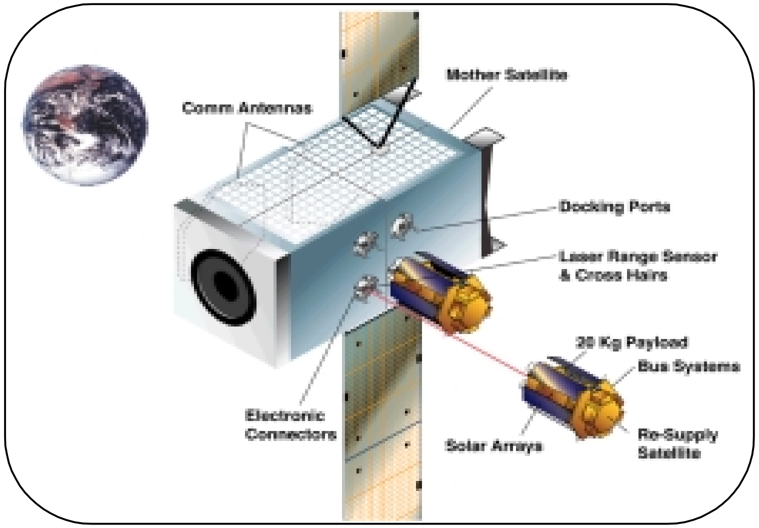
dwhelan@darpa.mil

(703) 696-2307

Aerospace Legacy and Vision



Orbital Express



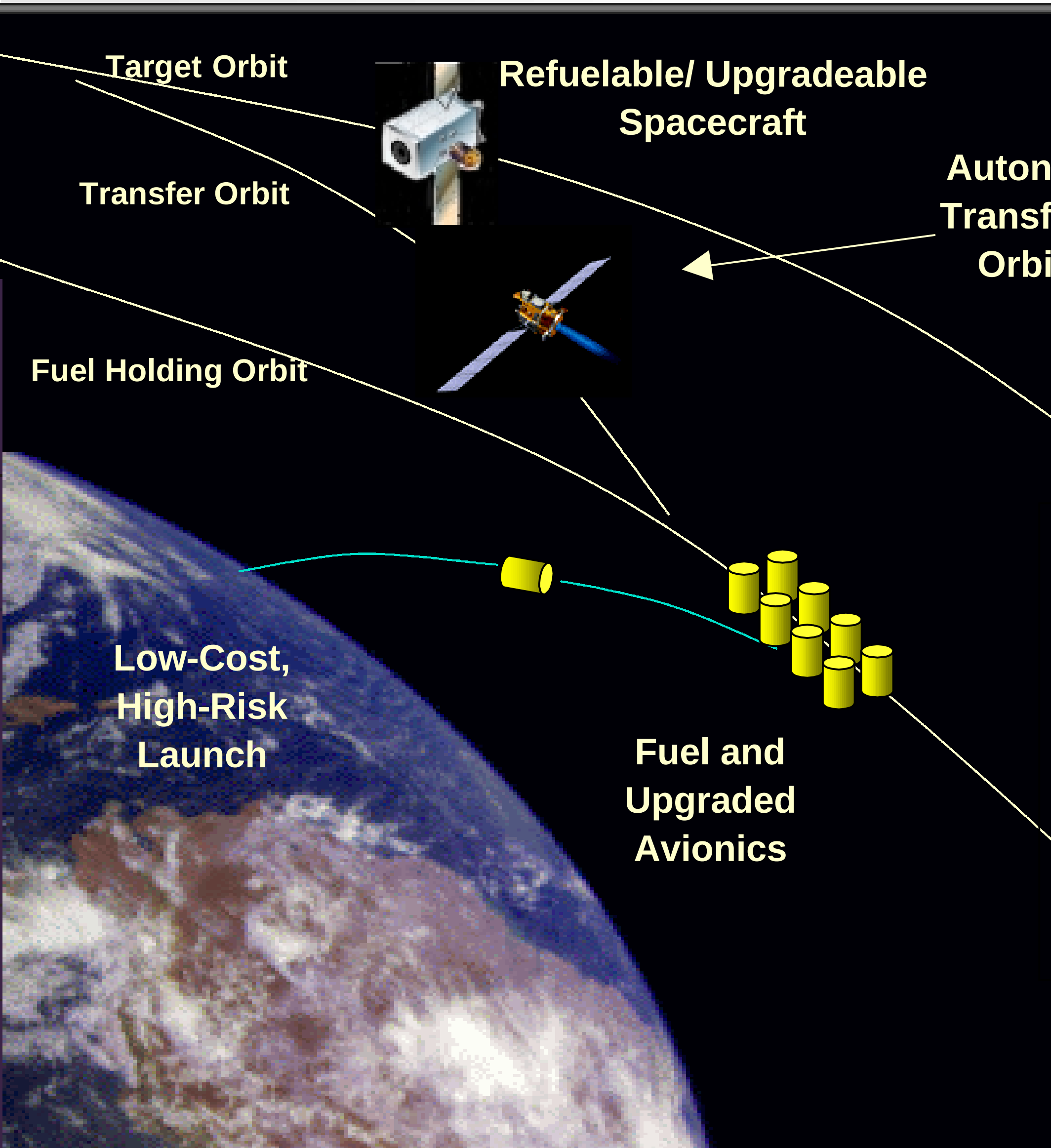
Extend Moore's Law to Space

Orbital Express
Today's DoD Space Architecture Limits

- **Operational**
  - System availability concerns force risk intolerance
  - Predictable orbits allow scheduling by adversaries
  - Orbital infrastructure does not account for vulnerability
  - Limited ability to tactically optimize orbital configuration
  - Finite fuel restricts utility
- **Costs**
  - Complex, highly redundant, cross-strapped designs
  - Manned servicing is cost prohibitive —$2M+ /orbital-hr
  - High fuel fraction costs for "maneuverable" satellites
- **Technology**
  - On-orbit technology at least 10-15 years old
  - Unmanned satellite servicing requires development

2010 Space Architecture

- The Long View-



Orbital Express

- Fly satellites — strategic and tactical mobility
- Space commodities — satellite replenishment and satellite avionics (ORUs)
- Water-based fuel “economy”
- On-demand, low-cost, small-payload launch

The Military/Intelligence Advantage

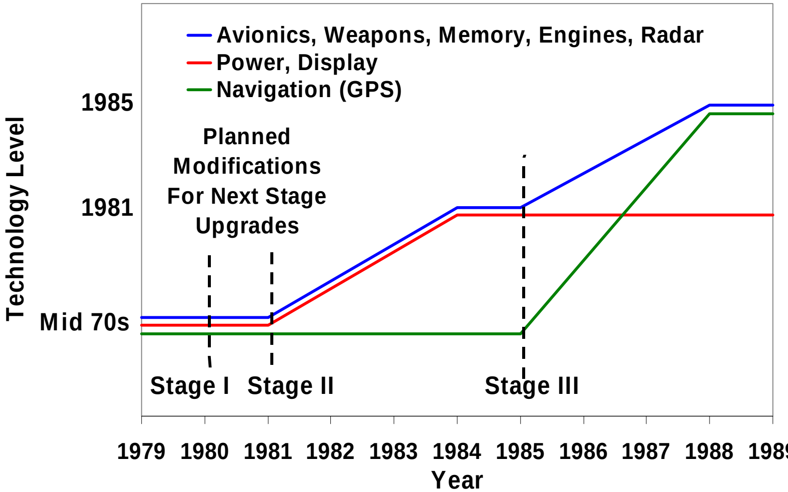
- **Enable new and enhanced capabilities**
  - Adjustable satellite coverage / optimization
    - Optimize “thin” constellations to provide regional focus (greater coverage)
    - Operate at different altitudes as needed
    - Formation “flying”
  - Random ΔV: Counter adversary activity scheduling (D+D)
  - Enable attack-mitigation options
    - Evasive and unpredictable maneuvers
  - Leverage long-lived hardware — reduce cost, increase capability
    - Extend lifetimes
- **Enable a revolution in space affairs**
  - Extensible Design & Commodities⇒COMMERCIAL Advantage for US Industry

Planned System Upgrade Standard Procedure for Aircraft

- **F-16 Multinational Staged Improvement Program (MSIP)**
  - Plan progressive upgrades
    - airframe life is long - technology evolving slowly
    - avionics technology progressing quickly - short obsolescence cycle
  - Retrofit upgrades to earlier F-16s
    - early airframes configured to accept future upgrades
  - Upgrade
    - processing speed, bandwidth and memory
    - defense capability, displays, weapons and warning systems
    - communications and navigation (GPS)

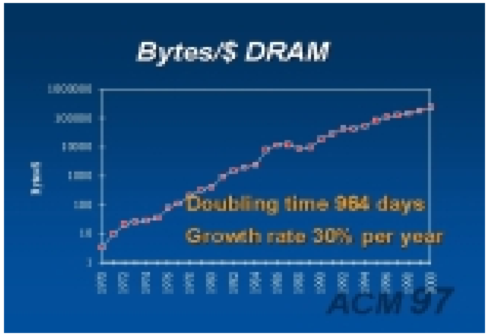
- **Advantages**
  - Increase service life and capability
  - Reduce cost and time to retrofit

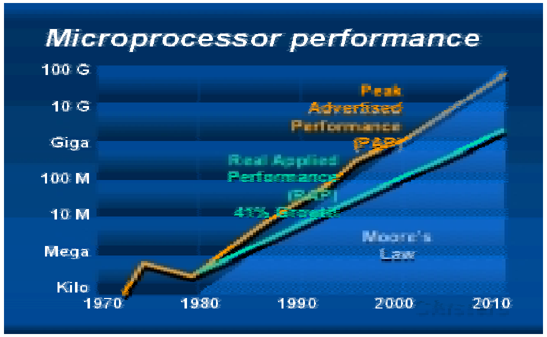
F-16 MSIP Planned Upgrades



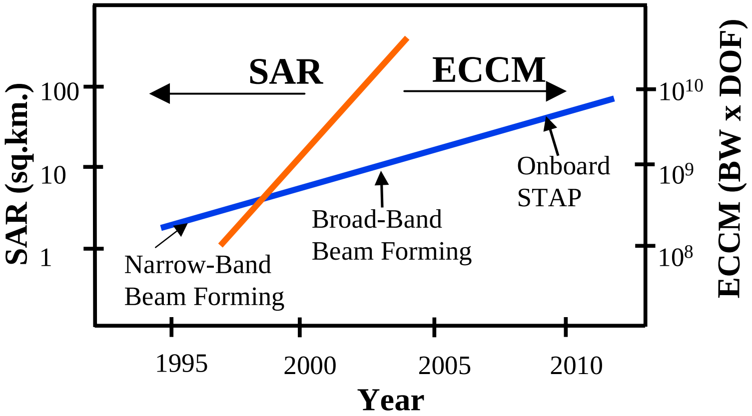
P³I Satellite Architectures
Extend Moore's Law To Space

- **Accommodate differing rates of technology advance**
  - Small ORU greatly improves system performance over time
  - "Plug-and-Play" architectures can be made highly adaptable
  - Exploit long-lived components (bus, sensors, solar panels)
- **Enable New Capabilities**
  - "Tightly coupled" systems— cross cueing/ tasking of new systems
  - Adapt to counter-measure threats
- **Less initial risk reduction required on upgradable avionics**
- **Reduction in satellite systems' costs**



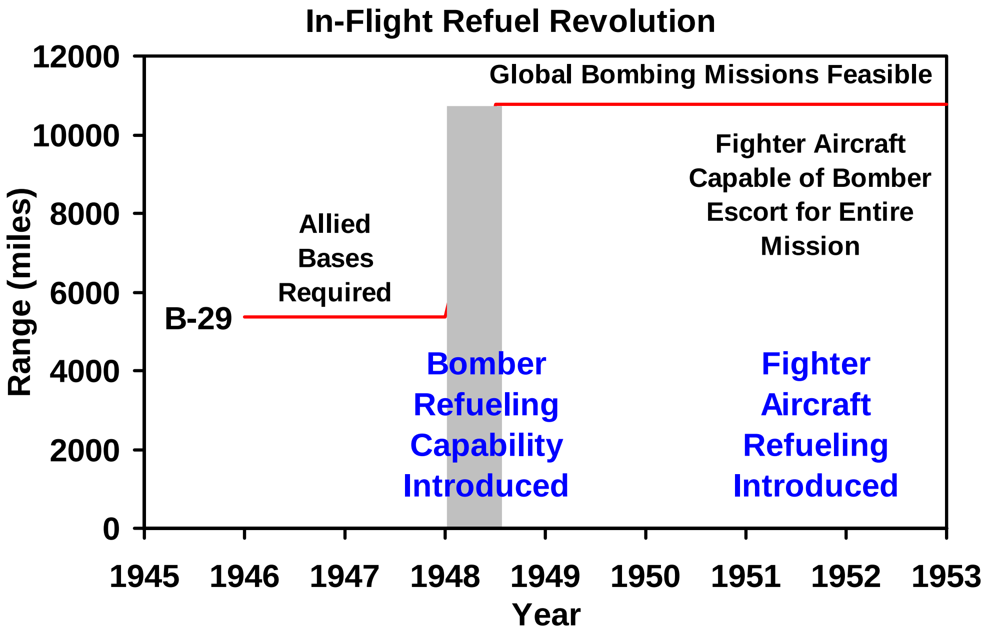


Spaceborne Processing



In-Flight Refueling - A Revolution in Military Aircraft Capabilities

- **Revolutionize aircraft missions**
  - extend range and duration
    - global missions feasible
    - fighter escorts sustainable
- **Reduce cost and time compared to base refueling**

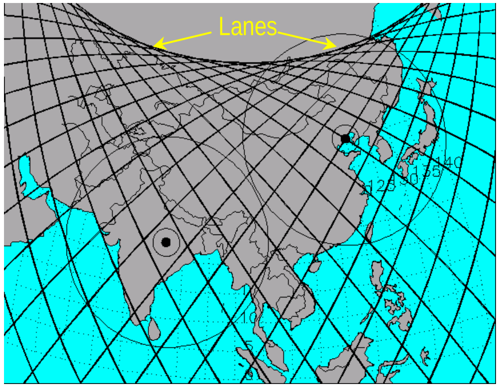


On-Orbital Refueling

A revolution in military spacecraft capabilities?

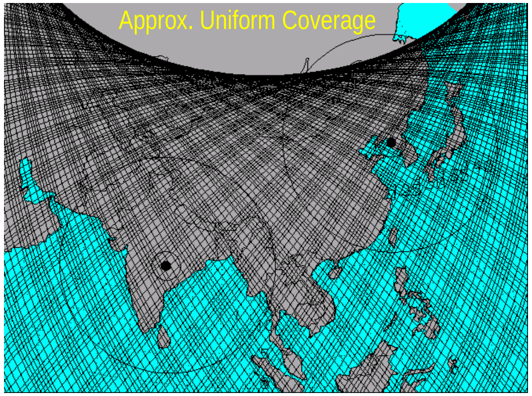
- **Optimize “thin” constellations to provide regional focus**
- **Operate at different altitudes as needed**
- **Extend lifetimes — don’t end mission due to lack of fuel or cryogen**
- **Evasive and unpredictable maneuvers**
- **Auxiliary peak power generation**
- **Formation “flying”**

Optimized



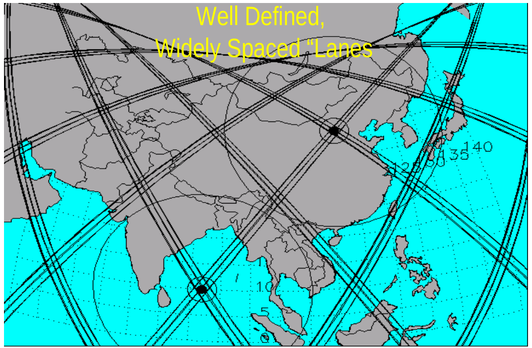
Walker 24/8/6

Dicoverer II Walker (24/8/4)

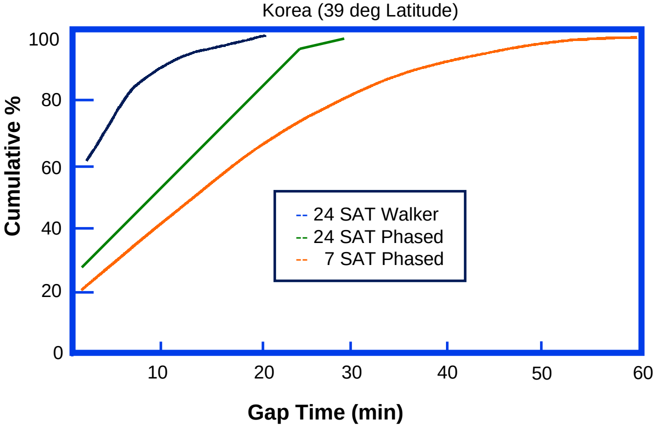


Thinned

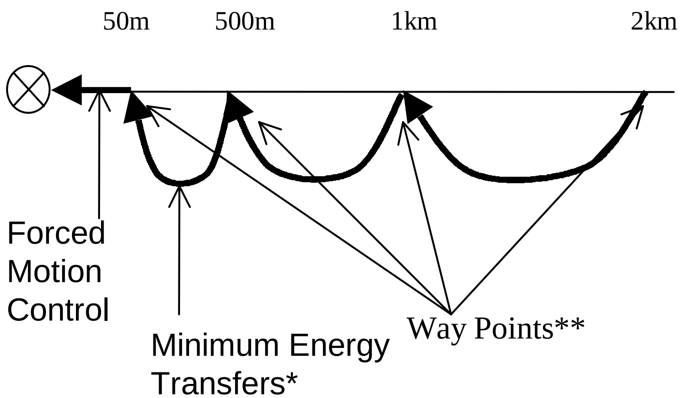
Walker 7/7

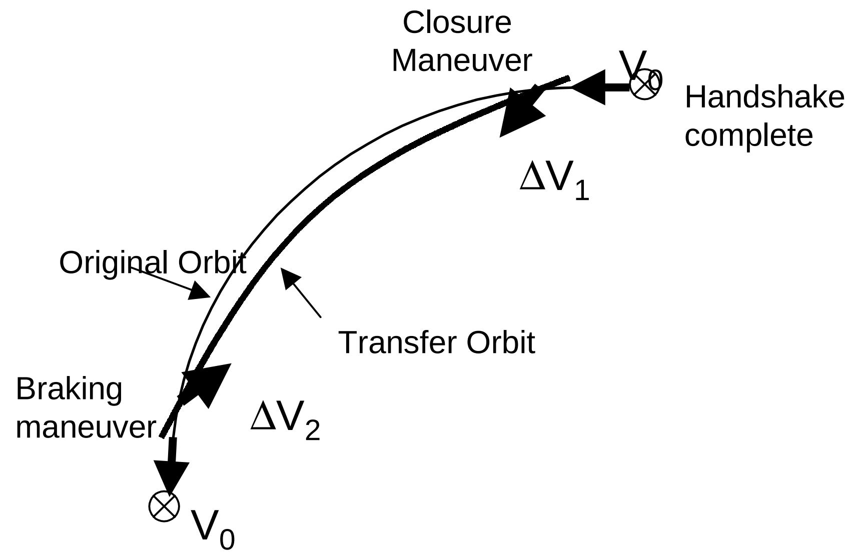


Korea: Cumulative Chance of Gap



New Operational Scenarios





Current State of the Art Operational Scenario:

- fuel efficient
- autonomous between waypoints
- man-in-loop at every waypoint
- time-consuming
- conservative from safety point of view

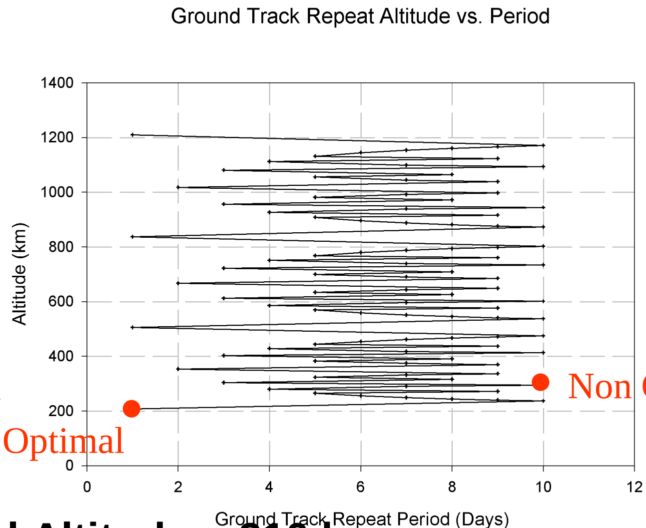
Orbital Express Operational Scenario:

- faster
- fuel intensive
- dependent upon autonomy
- minimal interaction with ground

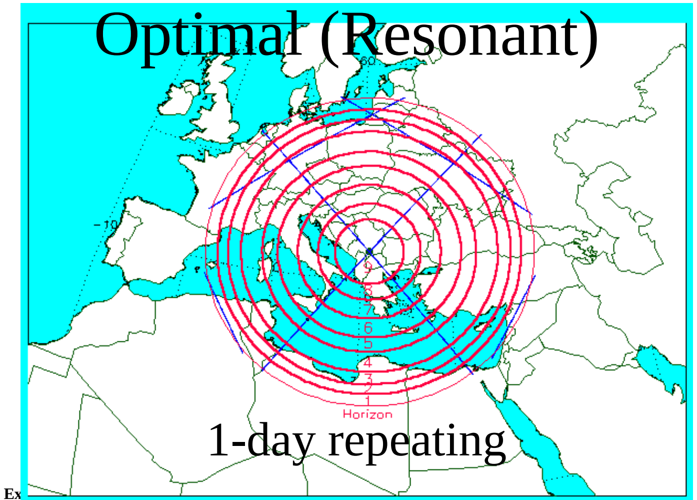
The faster, autonomous rendezvous procedure leverages the availability of fuel on orbit.

Resonant Altitudes Change the Character of EO/IR Orbits

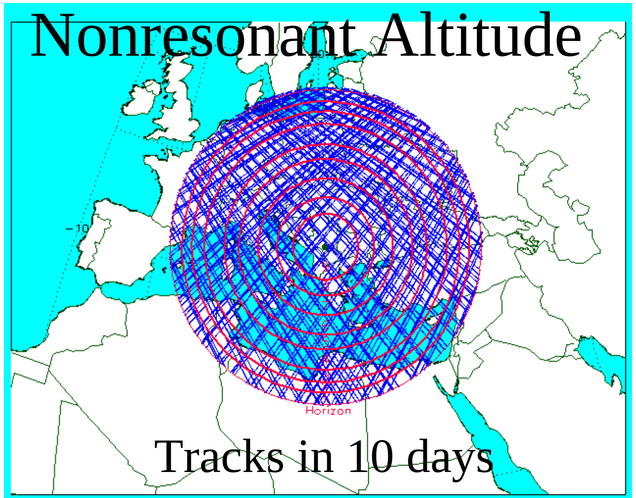
Areas under the repeating ground tracks receive greatly increased coverage, while remaining areas receive diminished coverage.



Inclination = 60.3 deg , Initial Altitude = 210 km

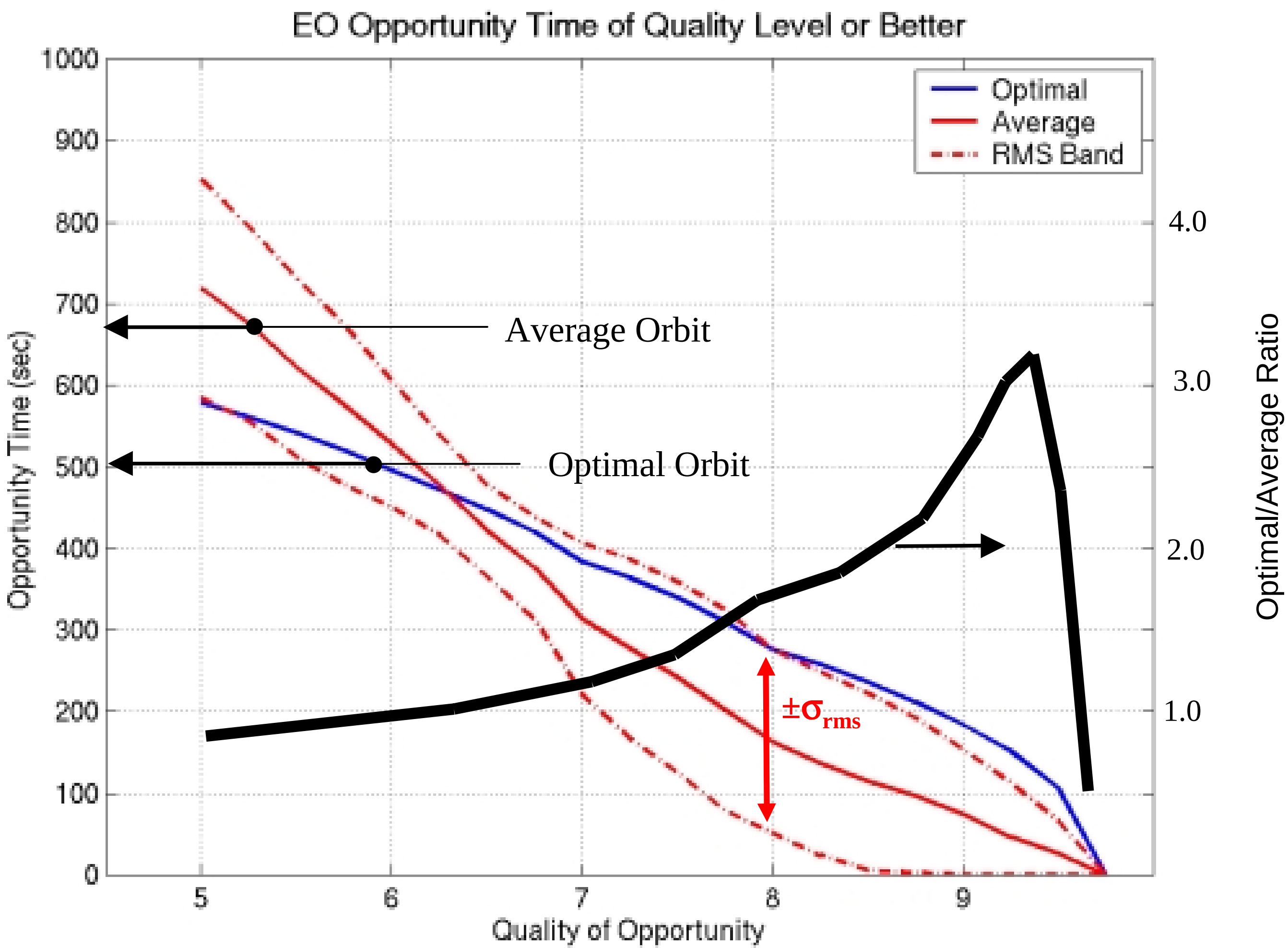


Altitude Change

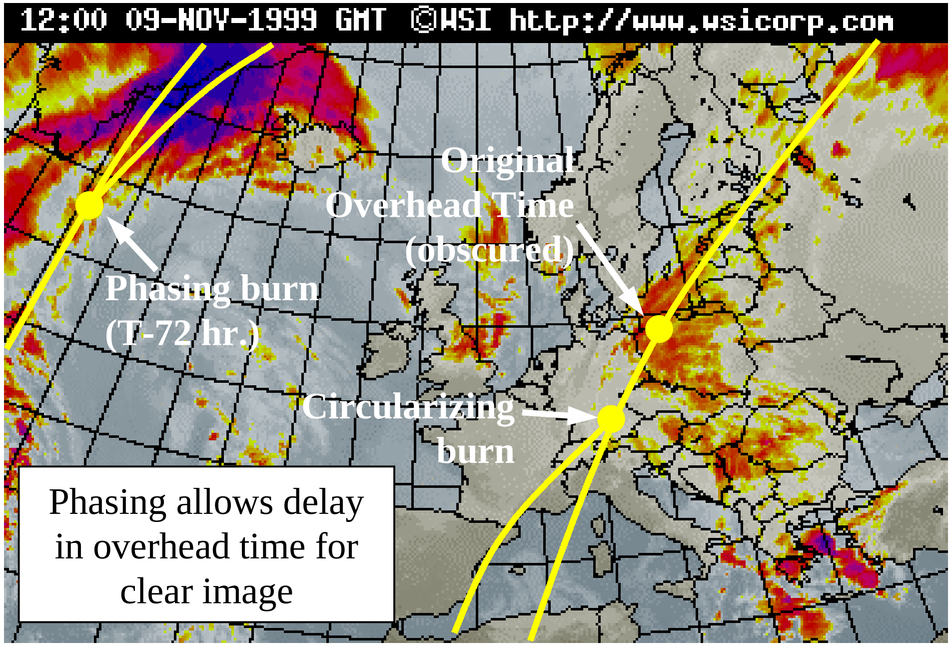


High Image Quality Opportunites via Resonant Orbits

- Ability to adjust orbital altitude can dramatically increase the opportunities for the highest quality EO/IR imagery of particular area
- Maneuver required to change area of interest



Phasing for Clearer Weather



Rephase to accommodate the forecast:
“In 3 days it will be cloudy in the AM, clear in PM.”

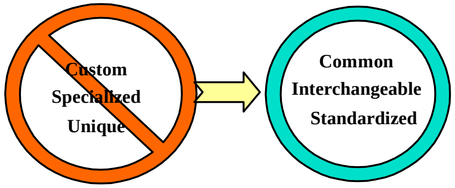
<u>Impulsive Burns</u>	<u>Continuous Low Thrust</u>
Isp = 350 sec	Isp = 1,500 sec
2 × 8 m/sec burns	0.5 N thrust
	2 × 16 m/sec burns

Perform one maneuver per month.
Fuel to be supplied to 10,000-kg S/C:

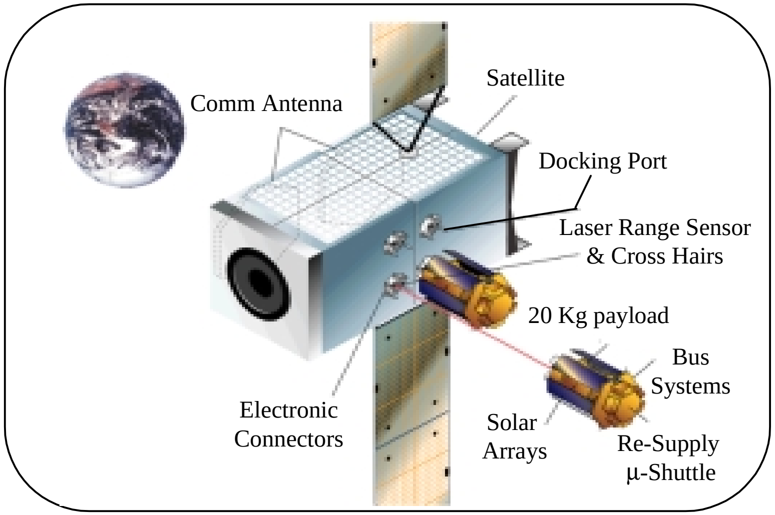
570 kg per year	260 kg per year

Refuelable & Upgradable Satellite Design/Architecture

- **Adaptable & Mission Capable**
- **Preplanned Product Improvement (P^3I) Satellite Design**
  - Extensible avionics (upgrade by "plug & stay")
  - Refuel (propulsion, cryogenics & other)



- **Spacecraft Features**
  - Common interfaces
    - Thermal
    - Signal
    - Power
    - Inertial
  - "Plug and stay" ORUs for Avionics P3I
    - Electronics
    - Power systems
    - Stabilization
    - RF elements
  - Replenishment
    - Fuel, Batteries, Cryogens



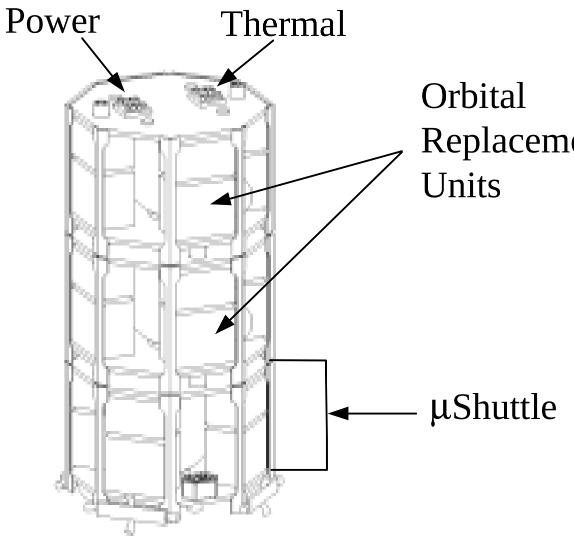
ASTRO (μ-Shuttle)
Autonomous Space Transporter and Robotic Orbiter

Micro shuttle functions

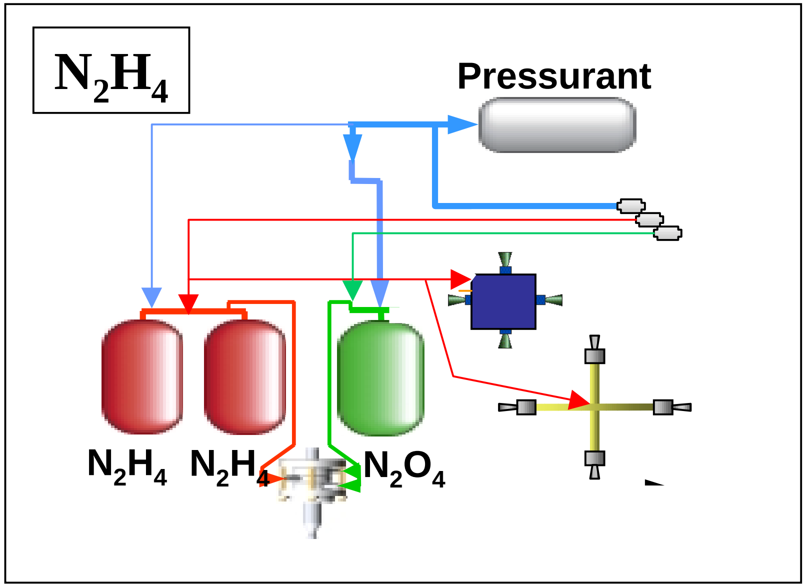
- Avionics/Fuel Canister capture, transport
- Autonomous satellite rendezvous & docking
- Inspection
- Orbital Replacement Unit delivery
- Fuel-conserving, constant-inclination “phasing” maneuvers
- Aero-assisted plane changes

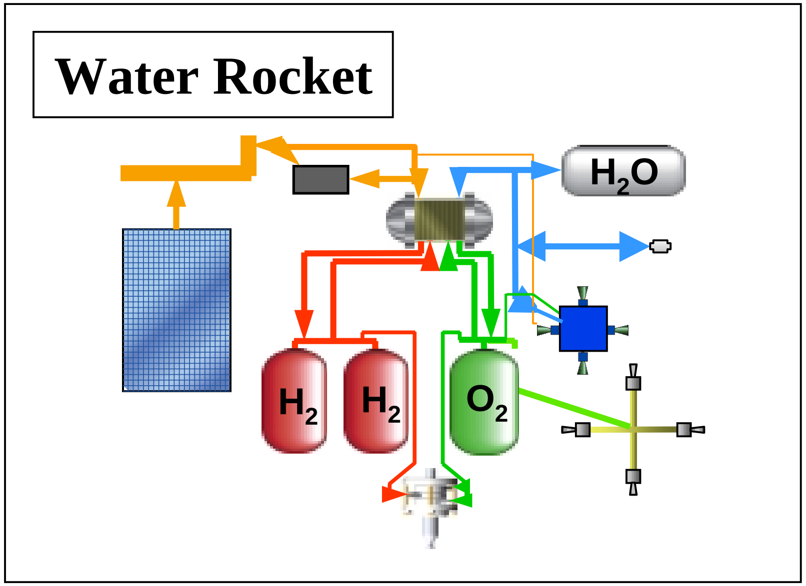
Technical challenges & opportunities

- Autonomous rendezvous / precision docking
- Soft capture mechanism
- Electrical / photonic / thermal interfaces
- Attitude control



Alternative Fuels



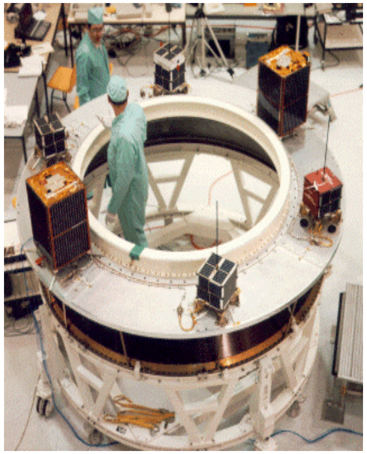


- **Fuel attributes**
  - High Isp
  - Long-term on-orbit storage
  - Relatively non-hazardous at launch
  - Multi-mode
  - Multiple resupply options

- **What is the right fuel infrastructure?**

Delivering Low Cost Material To Space

Launch Option	Average Cost
Dedicated	$ 5,000 - 10,000 / lb.
Piggy Back/Adapter Rings	$ 1,000 - 2,000 / lb
High Tempo - High Risk/Low Cost	$?
Gun Launch from Earth	$?



Key Technologies for Satellite Servicing

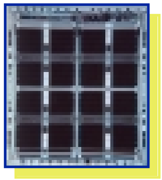
- **A supervised autonomy capability**
  - real-time mission planning on-board the service vehicle
- **An advanced GN&C algorithmic framework for the utility service vehicle**
  - improved on-board guidance (for non-impulsive burn planning)
  - improved on-board navigation (sensors and filters)
  - precision control algorithms for maneuvering for close-in proximity maneuvering
- **A replaceable avionics architecture for the serviceable satellite**
  - “Plug and Stay” avionics that conform to a common standard
- **Miniature avionics for serviceable vehicle**

Orbital Express
Why Now?

- **Enabling technologies have emerged**
  - High bandwidth communications for real-time telepresence
  - Improved sensors (cameras, radars, DGPS)
  - Efficient propulsion — ion engines, solar cells, water rocket
  - Modular spacecraft design with photonic, heat, mechanical, electrical interfaces
- **Military needs**
  - Strategic & Tactical maneuverability — enhanced coverage, counter-denial & deception, survivability
  - Large satellites have cost benefits from life extension
  - Other classified military needs
- **Response to change**
  - Rapid evolution of technologies
  - Continually evolving military/ intelligence priorities
  - Commercialization of space
  - Space commodities
- **Technological Surprise → Potential loss of U.S. leadership**
  - NASA's funds increasingly committed to manned space station
  - ESA & Japan see unmanned systems as an "end-around"

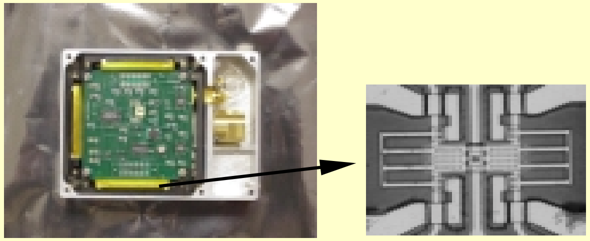
New Space Force Ideas

- Continuous Surveillance, Tracking and Targeting from space
- Tactically agile satellites
- Fuel and avionics as space commodities
- Evolvable spacecraft and system capabilities



Non-Volatile Radiation Hard Memory

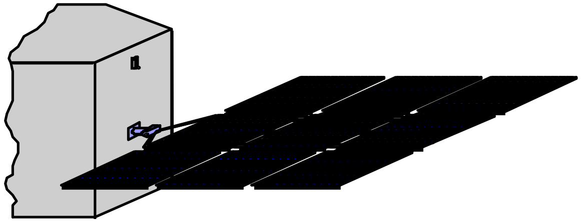
Discoverer II



2.5 x 7.5 x 10 cm 250 gm

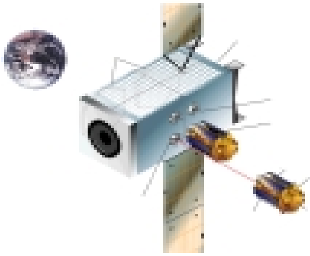
MEMS RF switch

Pico Satellites



Thin Film Photovoltaics

Flywheels



Orbital Express

What you will hear today:

- **AFSPACECOM future direction**
- **Existence proofs**
  - Utility analysis
  - On-orbit docking
  - Autonomy
  - Satellite standards/fluid transfer
- **Feedback from industry**
  - We want to hear your ideas